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BARRIER AND BUFFER FLUID SELECTION AND CONSIDERATIONS FOR MECHANICAL SEALS

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ABSTRACT

The increased use of pressurized and non-pressurized dual mechanical seals has driven more installations to require the use of barrier and buffer fluids. While some end users have viewed the selection of barrier fluids as an afterthought, their selection is a critical aspect of the seal operation and reliability. A thorough application review requires an understanding of the mechanical seal, sealing system, pump, and process. Fortunately there is a large installed base of successful installations to guide barrier and buffer fluid selections. Through the careful selection of fluids and good operating practices, barrier and buffer fluids can help provide reliable dual seal operation.

INTRODUCTION

Mechanical seals operate with a thin fluid film between the seal faces. This thin fluid film provides lubrication and hydrostatic load support to help control the tribological interaction and contact pressure between the faces. By definition then, the properties and stability of the fluid film help determine the reliability of the mechanical seal.

Barrier and buffer fluids help create the sealing environment for dual liquid seals. In Arrangement 2 designs, the buffer fluid provides the environment for the outer seal as well as supports the operation of the inner seal. In an Arrangement 3 design, the barrier fluid provides the fluid film for both the inner and outer seal and allows the seal assembly to be less dependent on the process fluids in the pump. Barrier and buffer fluids then are not a casual consideration in dual seal applications but are an integral part of a seal and sealing system design. The selection and maintenance of these fluids are as important to the success of the application as the details of the seal and piping plan.

While it may seem that any liquid could serve as a barrier or buffer fluid, in practice, relatively few fluids have been used successfully in the field. These fluids provide a unique combination of attributes such as good lubricating properties, low viscosity, and process compatibility. They must be environmentally safe, readily available, and competitively priced. They range from simple fluids such as water to highly engineered lubricants such as polyalphaolefin (PAO) lubricants designed specifically for mechanical seal systems.

Historically, the selection of barrier or buffer fluids has been an afterthought for many installations. In some cases, the selections were based on fluids already in use in the plant. In other cases, it was based on the latest sales literature from barrier fluid suppliers. In their evaluation, however, end users and seal supplier sometimes failed to consider both the steady state and upset condition in the pump on the performance of the barrier fluid. They also failed to consider the effects of contamination of the buffer fluid on seal performance. These can result in the barrier or buffer selection not being optimal for the application resulting in reduced equipment reliability.

The purpose of this tutorial is to help users understand the considerations in properly selecting and using barrier and buffer fluids. This will include a list of recommended barrier and buffer fluids. It will also give a background on the characteristics of good barrier fluids, testing and evaluation of barrier fluids, and fluid properties for many common fluids. The purpose of this document is not to document the largest possible list of acceptable fluids but rather to create the smallest list of fluids which can address the majority of applications in the field.

SELECTION CONSIDERATIONS

Selecting the correct barrier or buffer fluid is a critical step in specifying a sealing system. While there are a large number of barrier and buffer fluids which could be used, engineers should consider limiting the selection to a small number of fluids which have a proven installed base such as those described in Annex A.

It is easy to consider a barrier or buffer fluid only in terms of its lubricating properties; however, the fluid serves a number of other functions and must possess certain characteristics for successful use in mechanical seals. Each of these topics has specific considerations which should be addressed prior to the final selection.

Have adequate properties for lubrication of the seal faces

Mechanical seals operate with a thin liquid film between the faces. The fluid must have properties which allow the faces to operate under the application conditions and provide adequate lubrication. This is a function of the lubricity of the fluid, the viscosity under operating conditions, and the presence of additives or other contamination. The barrier or buffer fluid must also provide good lubrication for the specific face material combination in the application.

Have a viscosity which is low enough to allow for easy circulation

In Plan 52 or Plan 53 systems, the buffer or barrier fluid is circulated by the pumping action of the pumping device in the seal assembly. Standard seal OEM pumping devices (or pumping rings) have proven to provide adequate circulation in fluids with low viscosities. When using high viscosity barrier fluids, though, the reduction in head and the increase in pipe friction may reduce the flow rate to the point where the seal's performance is compromised. The barrier fluid needs to be evaluated not only at operating temperatures but also under start-up or stand-by conditions. This is especially important in areas where the seal reservoir may be exposed to very cold ambient conditions.

Have a viscosity which is low enough to minimize heat generation in high speed applications

Seals generate heat due to the effective coefficient of friction (including fluid shear) between the faces and by turbulent heat generated by the rotating seal components. On moderate sized seals operating at synchronous speeds, this heat generation is easily controlled by standard piping plans. On larger seals operating at high speeds, high viscosity barrier or buffer fluids may generate significant heat input resulting in excessive thermal distortion of the faces, high barrier fluid temperatures, and degradation of the barrier fluid. High speed applications should carefully consider the thermal aspects of the system and use a barrier fluid with an appropriately low viscosity.

Have a viscosity which is low enough to prevent blistering of a carbon seal face

Carbon is an excellent seal face material. When run against any common hard face material, the carbon provides low friction, low heat generation, and some self-lubricating properties. When carbon is used in high viscosity fluids, the shear forces between the seal faces may damage or blister the carbon resulting in excessive leakage. To prevent blistering, the viscosity of the barrier fluid must be low (generally less than 20 cP) or the seal face materials may need to be changed to hard vs. hard combination.

Be stable and not flash, degrade, or solidify under operating temperatures

Any liquid will have changes in its fluid properties as a function of its temperature. A barrier or buffer fluid may have suitable fluid properties under ambient conditions but have changes in properties under operating conditions which make it unsuitable for a specific application conditions. This requires that the user examine the expected temperatures of the barrier or buffer fluid at not only the extremes of the operating conditions but also the extremes of stand-by, cleaning, or other conditions that the fluid may be exposed to.

Be environmentally safe and not create health or safety issues

Barrier and buffer fluids must be considered in terms of their effect on personnel safety and environmental conditions. Before selecting a fluid, the user should consider the effects of personnel exposure during commissioning, seal failure, and equipment maintenance. Barrier or buffer fluids may also leak to atmosphere and this leakage should not violate any environmental regulations or permitting requirements. The selected barrier or buffer fluid should help mitigate the hazards of process leakage without introducing new concerns for the operator.

Be compatible with the process fluid

Both barrier and buffer fluids will mix with the process fluid. In a Plan 53, barrier fluids will leak into the pump and mix with the process in the seal chamber and the casing of the pump. This mixing must not cause an adverse chemical reaction or negatively impact pump performance. In a Plan 52, process will leak into a buffer fluid system and mix in the piping and reservoir. This mixing must not result in a degradation of the buffer fluids properties.

Be acceptable for leakage into the process fluid

In a Plan 53 or Plan 54 system, barrier fluid will be introduced into the process stream. In normal operation, inner seal leakage will be very low. In the case of seal failure, considerably more barrier fluid may enter the process. This must not cause complications with downstream processes or cause unacceptable contamination of the process stream. In addition, the user should be aware of any effects the fluid may have on operation of the pump such as flashing in the pump casing in hot services or solidifying in the pump casing in cryogenic services.

Be compatible with materials of construction of the pump, seal, and seal support system

In general, barrier fluids are not chemically aggressively towards materials commonly used in mechanical seals or seal system components. The user however needs to check the chemical compatibility of all components including gaskets and secondary sealing elements with the barrier fluid under operating conditions. This includes not only materials in the seal but also in auxiliary equipment such as reservoirs, seal coolers, or accumulators.

Be readily available and reasonably priced

Many end users think that the ideal barrier fluid is a fluid which is manufactured at their facility. Unfortunately, this is seldom the case. The most effectively barrier and buffer fluids are often fluids which are specially formulated for this application. These fluids are priced higher than many commercially available lubricants. Seal OEMs also need to be aware that the availability of specific fluids may vary significantly in different parts of the world.

Have a suitably large installed base of successful applications

A large installed base of applications can provide useful insights into the performance of barrier and buffer fluids under real world conditions. Examine the installation and performance records of referenced pumps and seals to confirm a barrier or buffer fluid is suitable for a specific application.

Barrier and Buffer Fluid Descriptions and Properties

Barrier and buffer fluids come in a wide range of chemical compositions and fluid properties. Appendix A lists a number of recommended fluids along with general comments on their use and other considerations. The actual determination of their suitability for a specific application requires a deeper understanding of the fluids and properties. The characterization of barrier and buffer fluids can be simplified by dividing them into basic categories.

Water

Water is the most universally available fluid in any industry. Whether water is a used as a part of the process or is available as a utility, it can be found throughout any plant or facility worldwide. This would satisfy one of the primary considerations for barrier fluid; it is readily available. It is environmentally acceptable and has no health and safety restrictions. It also has a high specific gravity and specific heat which aids in heat transfer. For all of its favorable properties however, water has severe limitations as a barrier fluid.

Pure water is a poor lubricant. At ambient conditions, water has viscosity that is suitable for lubricating seals with carbon vs hard face combinations. The viscosity decreases rapidly as the temperature increases. By 71°C (160°F), the viscosity is low enough that the fluid film in a standard seal fails to support the face often resulting in higher wear rates.

The low viscosity of water can also create problems for Plan 54 systems. Many Plan 54 systems are designed as an open system and use a positive displacement pump to create pressure and circulate the barrier fluid through the system. Many of these positive displacement pumps are designed with rubbing or sliding pump components that are designed to operate on a lubricating fluid. Operating these pumps on water can greatly reduce the reliability of the Plan 54.

Water at low temperatures can introduce different concerns. At 0°C (32°F), water freezes. This can have a severe impact on the condition of the seals and the auxiliary components. When a pump is in operation, the water barrier fluid may be heated by the process or the seal generated heat. In standby service though, the barrier fluid may reach ambient temperature conditions.

Water is relatively non-corrosive but it will rust wrought and cast carbon steels. Normal seal piping plans will use stainless for most components but may use carbon steel for the reservoir to reduce cost. Water barrier or buffer fluid systems must be designed with non-rusting materials. Not all water supply systems have clean, pure water. Contamination in the systems (e.g. rust or dirt) as well as water treatment chemicals (e.g. descalers, rust inhibitors, biocides, etc.) may affect chemical compatibility of the seal components or the lubricating properties between the seal faces. Users must ensure that the water supply is clean and suitable as barrier fluid.

One of the primary reasons why water is selected as a barrier fluid is for compatibility with the process fluids. In normal operation, small amounts of barrier fluid will leak into the process. In some processes, pure water introduced into the system would not be considered as a contaminant in the process. Water, specifically condensate, is the most common barrier fluid in the food processing, pharmaceutical, and biotech industries.

Glycol/Water Mixtures

Many of the shortcomings of water can be addressed by mixing the water barrier fluid with other chemicals. The most common mixtures are water with either Ethylene Glycol (EG) or Propylene Glycol (PG). The addition of a glycol to the water depresses the freezing point and elevates the boiling point. It also increases the viscosity of the mixture which can provide better lubrication to the seal faces. It does this while still maintaining the high specific gravity and specific heat required for effective heat transfer. The improved properties made this buffer fluid an industry standard in refineries in light hydrocarbons services for many years.

Ethylene glycol is commonly used as a heat transfer fluid in industrial applications and automobile cooling systems. Automotive anti-freeze is most commonly a mixture of EG and other chemical additives. These other additives provide useful properties to automotive applications including preventing rust and corrosion, descaling metal surfaces, and stopping leaks in the cooling system. While these additives enhance the performance in automotive applications, they can cause high wear on the seal faces and reduce the reliability of the seal. For this reason, automotive anti-freeze should not be used in barrier or buffer fluid systems. Only pure EG or PG should be used.

While ethylene glycol improves the properties of the barrier fluid, it has the drawback of being mildly toxic. Casual exposure to the skin is not considered a significant hazard but it must not be ingested and leakage into the environment may be regulated. For these reasons, many users have switched to propylene glycol/water mixtures. The properties of PG/water and EG/water are comparable and they will provide similar performance in most applications. Propylene glycol is considered non-toxic and is safe for human exposure. Food grade PG is available and can be used in many food handling processes. Propylene glycol should be the first choice for glycol/water barrier and buffer fluids in most applications.

Alcohols

Alcohols are a class of organic compounds which covers a wide range of molecular weights, chemical structures, and physical properties. Simple alcohols, such as methanol, ethanol, and propanol are low viscosity fluids which are liquid under moderate ambient conditions. At these temperatures, the low viscosity and poor lubricating properties make them unsuitable for maintaining a stable fluid film. Their high vapor pressures and tendency to evaporate quickly add to the list of characteristics which would make them seem unsuitable as a barrier fluid. There is however one physical property which is unique compared to other barrier fluids; their ability to remain in a liquid phase and have a moderate viscosity at very low temperatures.

Cryogenic temperatures are not uncommon in some refinery or petrochemical processes. In these applications, common barrier fluids will be very viscous or freeze. Simple alcohols such as methanol however will resist freezing down to approximately -98°C (-143°F). At these temperatures, the viscosity of the fluid can allow dual liquid seals to function acceptably. The seals and seal supports systems must however be designed to operate at these temperatures and prevent the temperature of alcohol barrier or buffer fluid from becoming too high. Historically, methanol was used for the applications. However, propanol provides a broader range of temperature capability and superior lubricating properties at ambient temperatures.

Petroleum Based Lubricating Oils

Crude oil based lubricants are one of the major products produced in any modern refinery. Through various distillation processes, the crude oil is separated into products ranging from light hydrocarbons to asphalt. In the middle of this range are products which range from low viscosity lubricating oils to heavy gas oils. Each product is a mixture of various lengths of hydrocarbons chains and their specific composition gives the oil its unique properties.

Lubricating oils are used on virtually every piece of rotating or reciprocating equipment in industry. Because there is a broad scope of equipment with a wide variety of lubrication needs, there is a correspondingly wide range of lubricating oils on the market. While all of these provide lubrication, their specific formulation, viscosity and additive packages are often tailored for the equipment and the operating conditions for a specific piece of equipment. In general, these modifiers negatively impact the unique lubricating requirements of mechanical seals.

Specialty Barrier Fluids

The increased use of dual mechanical seals has created a significant demand for specialty barrier and buffer fluids. These fluids have excellent lubricating properties, are available in a range of viscosities, and are free from additives which can negatively impact seal performance. These fluids are marketed from major refineries, lubrication manufacturers, and seal OEMs. In some cases, these fluids are used primarily within the manufacturer’s facilities (in the case of refineries). In other cases, certain formulations have seen wide acceptance across the seal industry.

Most successful specialty barrier and buffer fluid are based on synthetically created lubricants. These are commonly based on polyalphaolefin (PAO) synthetics. These fluids have a higher viscosity index than refined products. They have excellent chemical compatibility with most processes. They have good oxidation resistance and thermal breakdown properties. In addition, they can be formulated so they are safe for applications requiring FDA compliance.

Specialty barrier fluids are available with a wide range of viscosities that allow these fluids to be used over a broad range of operating temperatures. In high temperature applications, some end users will use very high viscosity barrier fluids since the viscosity will be correct while the pump is in operation and the barrier fluid is at operating temperatures. The end user must ensure that the fluid is maintained at a temperature where the barrier fluid viscosity does not become too high or solidify during stand-by conditions. High viscosity barrier fluids also require that the seal use a hard vs. hard face combination (e.g. SiC vs. SiC) to prevent blistering of a carbon face.

The high cost of the base stock and purity of the product make specialty barrier fluids more expensive than traditional industrial lubricants. This cost may make end users reluctant to use this class of fluids especially if they have large Plan 54 systems or a large number of dual seals systems to support in the plant. The high cost however is largely offset by the improved operating performance of the fluids in seal applications. The superior fluid properties of specialty barrier fluids may allow for standardization of a single fluid in most applications in a plant. Finally the stability of the fluid may allow for longer run times between fluid changes resulting in reduced maintenance costs.

Heat Transfer Fluids

Heat transfer fluids are specialty fluids which are designed specifically to handle the demanding application of heat transfer processes in industrial plants. Commercial heat transfer fluids have chemistries ranging from glycol based fluids to high temperature mineral oils to eutectic mixtures of specialty chemicals. These fluids are stable and can remain in a liquid phase over a wide range of operating temperatures. Compared to other liquids, their viscosity is relatively stable at extreme temperatures. While it may seem that these are desirable properties for a barrier fluid, heat transfer fluids are not formulated as a lubricating fluid. In most cases the fluid properties do not provide adequate support for the mechanical seal faces often resulting in high face wear, face blistering, chipping, and coking at the outer seal.

Heat transfer fluids are designed for operation at relatively high temperatures. The user must also ensure that the fluid will have suitable properties under the entire range of temperatures which may be present in the seal. Pumps in stand-by conditions may have barrier fluids near ambient conditions. If auxiliary equipment (e.g. reservoir) uses an air cooler or water cooler in the piping plan, the barrier fluid will reach the same temperatures as ambient air or cooling water, respectively. In cold climates, this may result very high viscosities and damage to the seal faces or poor circulation of the fluid.

In many modern processes, dual seals may be required for high temperature services for safety reasons. In heat transfer applications, often the only acceptable barrier fluid is a heat transfer fluid. This is due to concerns of the barrier fluid contaminating the heat transfer system. The high operating temperatures of the pump and the poor sealing properties of the fluid often create reliability problems for the seal. For heat transfer fluids to have acceptable performance as a barrier fluid the temperature should be maintained below 200°F. Even then, many heat transfer fluids may not allow for reliable seal performance. For this reason, heat transfer fluids are generally not considered as an acceptable barrier fluid especially if other fluids such as specialty barrier fluids are acceptable for the application.

Additives in Lubricating Fluids

Lubrication, in its simplest form, modifies the environment between two surfaces in relative motion by reducing friction and minimizing wear. In many applications (e.g. bearings), this is done by providing an adequate fluid film to completely separate the surfaces. In other applications (e.g. gears) there will be hard contact between the surfaces. To prevent damage to the metal surfaces, special additives (e.g. EP or “extreme pressure” additives) are added to the oil to prevent localized bonding of the asperities. Other operating conditions may require the oil have better resistance to high temperature oxidation (with antioxidants), reduced tendency to foam (with anti-foaming agents), be less corrosive to the equipment (with corrosion inhibitors). There are literally dozens of additives which are used to create the ideal formulation for a specific application.

Mechanical seals however operate in a very different mode than most other pieces of lubricated equipment. Mechanical seals operate in a boundary lubrication regime where there can be significant contact between the asperities on the seal faces. Additives which are very useful in other applications may prove to damaging in mechanical seals. For this reasons, barrier fluids are most often provided without any additives. This is true for oils or other hydrocarbons. It is also true for glycols such as Ethylene Glycol (EG) where pure EG should be used rather than automotive antifreeze. Lubricating oils, especially synthetic oils which are free from additives, provide better performance than typical lubricants used in industrial equipment.

Barrier and Buffer Fluid Testing and Results

The true test of a barrier or buffer fluid is how it performs in actual field applications. Fortunately, there is a large installed base of dual seals which can be referenced. Field data however can become complicated to interpret since seals are exposed to different process chemicals and operate under different application conditions. For this reason, it is helpful to test barrier and buffer fluids under a set of controlled conditions. This will allow for a relatively accurate comparison between various fluids under the test conditions. It is also useful to perform this testing to screen potential barrier fluid before putting them into field applications.

In industry, there is no standardized test procedure for evaluating barrier and buffer fluids. Seal OEMs have developed in-house testing methods and used these as the basis for their recommendations. This testing is also useful in identifying general trends in performance based on the fluids composition and the presence of additives. This testing however is not a blanket endorsement of a fluid since the fluid still must be suitable for the intended application.

Over the years, seal OEMs have performed numerous evaluation tests on a wide variety of commonly used barrier fluids. Some OEMs testing focused on measuring the following parameters:

Temperature rise : This parameter specifically measured the increase in seal face temperature over the seal chamber temperature. This is used as an indicator to establish the fluid shear and friction between the seal faces.

Standard Deviation of Face Temperature : This measurement analyzes the fluctuations or instability of the temperature between the seal faces. This gives an indication of how stable the fluid is during operation and how well the barrier fluid maintains an adequate fluid film.

Surface Roughness : Contacting wet seal operate with some mechanical contact between the faces. The test seal faces are measured before and after the testing to determine if there was excessive mechanical contact or wear on the faces and the characteristics of the wear surface.

This testing helped identify the general characteristics of barrier fluids that had the best test results. It also helped create initial lists of recommended barrier fluids. Over the years additional barrier fluids have been evaluated with this method in response to new product offerings, specific application requirements, or customer requests. Barrier fluid producers and seal OEMs can give additional guidance on specific testing that has been conducted by their organizations.

Barrier and Buffer Fluids in Operation

Selecting the correct barrier or buffer fluid is a critical step in ensuring the proper operation of a dual liquid seal. It is equally as important to ensure that the fluids are clean and properly maintained during operation. This means that from the time the fluid is purchased until it is disposed of, the end user practices must be directed towards optimizing seal performance.

Storage and Commissioning

Barrier fluids can be obtained in a number of ways. In some cases, the fluid may be a by-product of processes in the plant. In other cases, it may be commercially purchased in containers ranging from small cans to large drums or tanks. In all cases, the end user needs to establish procedures for delivering the barrier fluid to the required locations (e.g. reservoirs or supply tanks). In many plants, this is done by using small portable containers or fill cans. In other cases, end users utilize fill carts which contain a supply tanks, hand pump, and fill hose. In the most sophisticated systems, barrier fluid are distributed through hard piped systems which are designed to automatically refill fluids into the reservoir or sealing system. Regardless of how the fluids are distributed, the procedures must ensure that the fluid is properly identified and the storage and distribution practices ensure that the fluid is clean and does not become contaminated.

Each container of barrier or buffer fluid must be clearly marked identifying the name of the fluid. This is especially true if the fluid is transferred from its original container into another container such as fill cart or can. The equipment which uses the barrier or buffer fluid (e.g. reservoir or supply tank) must also be labeled to indicate the fluid it uses. For example, a fill cart or can should be marked “Brand X ISO 5 Barrier Fluid” and the corresponding reservoir should be marked “Use Brand X ISO 5 Barrier Fluid Only.”

Any can, fill cart, or other containers of barrier fluid must be stored in a way to prevent contamination of the container or fluid inside. This is best accomplished by only using closed containers and storing them in areas protected from rain, wash downs, or other sources of contamination. This includes containers which are empty but will be used for transporting barrier fluids. Large drums of fluid should be stored to prevent an accumulation of water on the top of the drum.

During commissioning, the end user must ensure that the reservoir, piping, tubing or supply tanks are clean and free from contamination prior to adding barrier or buffer fluid. This may involve flushing the piping system with a clean, compatible solvent prior to the initial filling.

Refilling During Operation

Barrier and buffer fluids will need to be added to the seal systems when the pump is in operation. This is considered a part of the normal maintenance for the piping plan. Safety is the primary concern when performing this function. In the past, end users might open a port at the top of a reservoir and simply dump fluid directly in using a funnel or fill can. Practices like this are no longer considered acceptable for safety and contamination reasons. There are three primary ways that barrier and buffer fluids are added to a system – fill connections, hand pumps integral with the system, and fill ports on supply tanks.

Fill connections are dedicated connections on reservoirs and may be connected to pressurized or unpressurized systems. Fill connections are most often a quick connect fitting which is connected to a check valve and block valve. The user will connect the hose from the fill cart to the fitting, open the block valve, and add the barrier fluid (often with a hand pump on the fill cart). The user will add the appropriate amount of fluid based on the piping plan.

Plan 52 and 53A: Fluid will be added until the level is near the middle of the site glass on the reservoir. (See Fig 1 and 2)

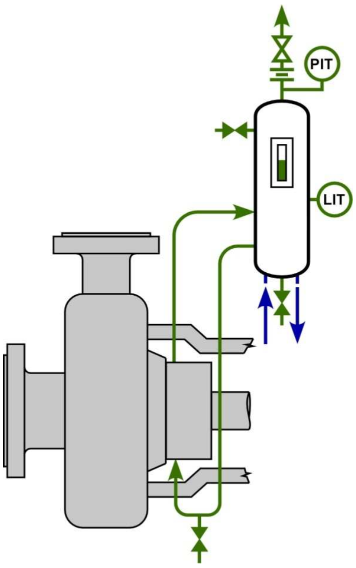

Figure 1. Plan 52

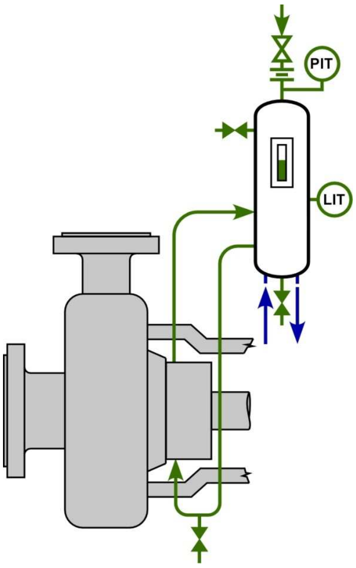

Figure 2. Plan 53A

Plan 53B: Fluid will be added until the pressure in barrier fluid reaches the recommended operating pressure for the application (See Fig. 3).The actual refill pressure will be specific for the specific application and will consider parameters such as the pressure in the seal chamber, the pressure rating for the seals, the size of the accumulator, and the required refill interval.

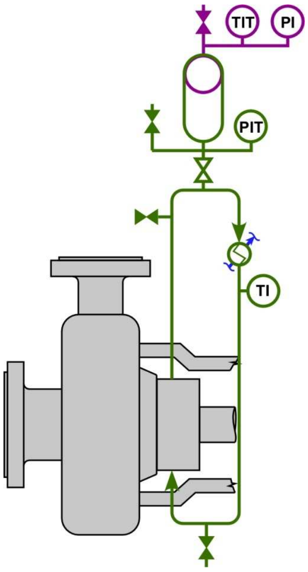

Figure 3. Plan 53B

Plan 53C: Fluid will be added until the piston rod in the accumulator extends to the designated high level position of the piston rod (See Fig. 4). The piston accumulator will create a high pressure in the barrier fluid system through the use of differential areas on the barrier fluid side and process side of the piston. The system is pressure energized by the process fluid and will track changes in pressure during operation. The user must take care in filling the system to prevent bottoming out the piston in the cylinder.

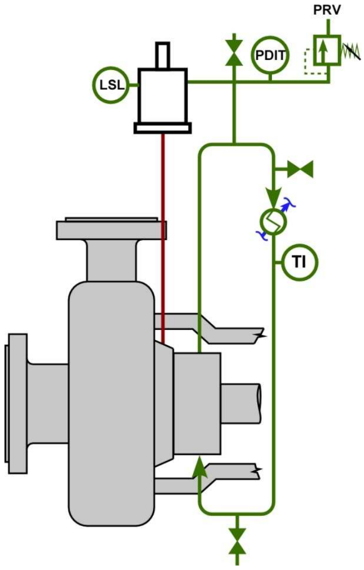

Figure 4. Plan 53C

Under no conditions shall the operator overfill any system. In the case of a Plan 52, this will only result in the annoyance of not being able to visually determine the reservoir level. In other cases like a Plan 53C, this may result in over pressurization of the system and subsequent seal or system failure.

Hand pumps may be an integral part of a piping plan or seal system auxiliary (See Fig. 5). A hand pump may be packaged with a reservoir or be part of a complete system such as Plan 53B. The hand pump will have a small atmospheric fill reservoir which is filled with barrier fluid. The hand pump then pressurizes the fluid and injects it into the reservoir or system. The user must fill the system to the appropriate level as described above.

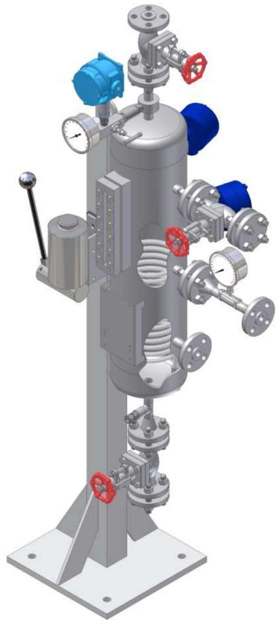

Figure 5. Reservoir with Hand Pump

Many end users utilize lubrications carts specifically designed for barrier and buffer fluid maintenance (see Fig. 6). These carts consist of a wheeled platform with a fluid storage tank, connection hose, and high pressure fitting. This allows for easy distribution of the fluid and minimizes contamination of the barrier fluid.

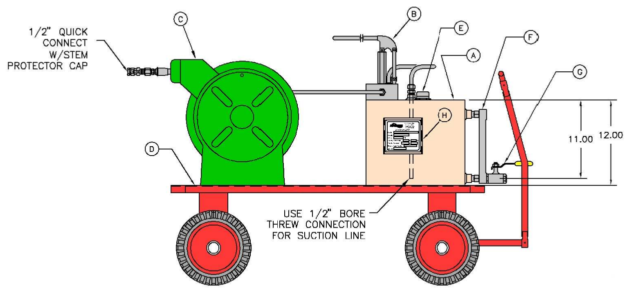

Figure 6. Example of Fill Cart

Plan 54 systems are most often barrier fluid systems which include methods for circulating, cooling, filtering, and monitoring the barrier fluid. "Open system" refer to the Plan 54s which utilize an atmospheric pressure supply tank. These supply tanks are maintained at atmospheric pressure and contain a breather cap and a fill connection. In most cases, barrier fluid is added to the supply tank by simply pouring the fluid through the open fill port. "Closed system" refer to Plan 54 where the entire system, including the supply tank, is maintained under pressure. These systems may have fill connection similar to Piping Plan 52 and 53A. Refer to the operations manual for your system to determine the procedure for adding barrier fluid.

Recommended Temperatures

All barrier and buffer fluids have recommended application temperature ranges. Examples of these are given in Appendix A. These ranges are based on the fluid physical properties and the fluid's stability. These temperature ranges though cannot be taken out of the context of proper seal and system selection and operation.

In very low or cryogenic temperature applications, the barrier or buffer fluid must remain in a liquid phase and at a reasonable viscosity. The fluid cannot freeze, solidify, or become extremely viscous. For this reason water or hydrocarbon based are not recommended for these applications. Alcohols like Propanol are more widely used. These fluids however have very poor lubricating properties at ambient temperatures. Another approach which is used in vertical pumps in cryogenic applications is to design the pump with a dead-ended cavity immediately below the seals. This warming chamber isolates the cold cryogenic temperatures from the seal and allows conventional seals and barrier fluids to be used. The user must be aware that some barrier fluid leakage may migrate into the pump. For this reason, the seal design may incorporate a leakage collection device which is designed into the inner seal to prevent barrier fluid from reaching the process fluids.

In high temperature applications, the fluid must also be stable and have a reasonable viscosity under operating temperatures. In most refineries, high temperature pumps are commonly operated well above the actual temperature rating for a barrier fluid. Most barrier fluids, even high viscosity fluids and synthetics will boil or decompose if exposed to these conditions. For this reason, piping plans will be selected to help control the temperatures at the seal. This includes the use of a Plan 02, Plan 21 (air cooled), Plan 23, or Plan 32 at the inner seal. Other design factors such as close clearance throat bushings, thermal bushings, and thermal breaks in the glands are used to reduce heat soak and lower the operating temperature of the barrier or buffer fluid. The barrier or buffer fluid system must be adequately sized to remove the heat soak and seal generated heat from the fluid while maintaining acceptable fluid temperatures.

There may other reasons why it is advantageous to control the barrier fluid temperature. Many plants have safety restrictions which require additional personnel protection for high temperature piping and auxiliaries. In addition, high barrier fluid temperatures can cause coking on the atmospheric side of the outer seal resulting in lower reliability. For these reasons, it is desirable to maintain barrier fluid temperatures below 90°C (194°F) in operation. Ideally, fluid temperatures should be maintained below 65°C [150°F] to reduce fluid degradation and minimize the operator's exposure to hot piping or reservoirs.

Barrier and Buffer Fluid Degradation

When barrier and buffer fluids are first added to a system, the user knows the condition and the properties of the fluid. After continued operation, these properties may begin to change and the user can be less certain of the actual condition of the fluid. While barrier and buffer fluids can run successfully for years, in many cases the fluid properties will begin to degrade as the fluids are exposed to temperature extremes and contamination from the pump and piping system.

Dual seals in high temperature applications will commonly show signs of barrier fluid degradation. Plan 52 and 53 seal assemblies are designed to circulate the barrier or buffer fluids through the piping plan and control the fluid temperature at an acceptable flow rate. While this is generally effective at keeping the bulk fluid temperatures in control, the fluid cavities around the inner seal are often isolated from the barrier or buffer fluid circulation and are exposed to high temperature. This is especially true for the area under the inner seal in a face-to-back orientation. Seal designs which create large areas and free circulation in this region can minimize this effect. Piping plans with large circulated volumes may allow for longer operation before the barrier or buffer fluid properties are adversely affected.

Buffer Fluid Contamination

Arrangement 2, dual unpressurized seals operate with the pressure of buffer fluid less than the pressure in the seal chamber. This results in a constant leakage of process fluids into the buffer fluid. In non-volatile processes, this results in a mixture of process and buffer fluid which can degrade the properties of the fluid. This can also result in an increase in process emissions to atmosphere as the concentration of the process fluid increases in the buffer system. In practice, though, the actual contamination of the process depends upon the properties of the fluids.

In many cases, process fluid that leaks across the inner seal will remain in a liquid phase. At one extreme, the process fluid may be completely immiscible and not mix with the buffer fluid. If the specific gravity of the process fluid is less than the buffer, it will migrate to the top of the system (See Fig. 6). If the specific gravity of the process is greater than buffer fluid, it will migrate to the bottom of the system (See Fig. 7). In practice, there is significant turbulence in the system and there will be some mixing. In Plan 52 reservoirs however it is not uncommon for the lower viscosity fluid to form a layer at the top and the higher specific gravity fluid to form a layer at the bottom of the reservoir.

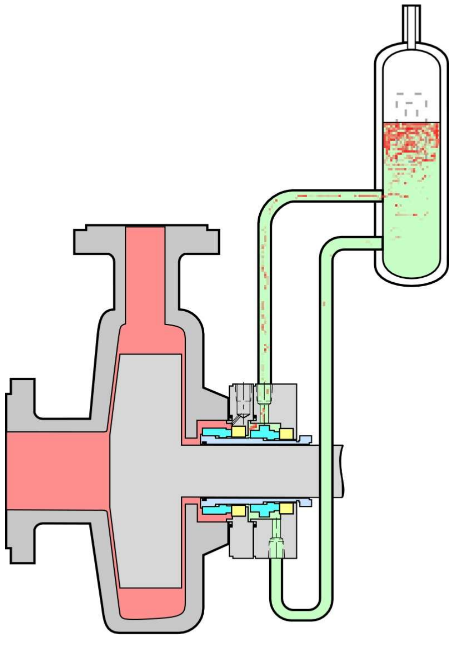

Figure 7. Process Fluid SG Less Than Buffer Fluid

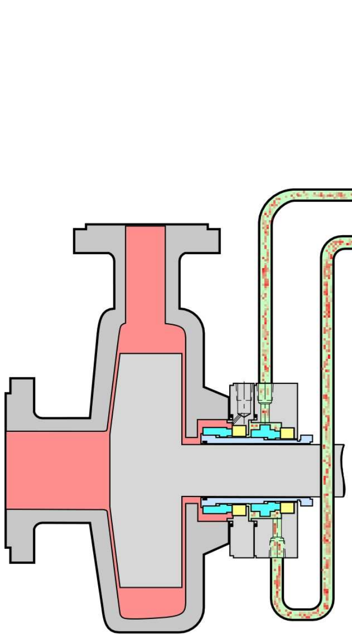

Figure 8. Process Fluid SG Greater Than Buffer Fluid

In other cases, the process fluid will be completely miscible and completely mix with the buffer fluid forming mixture throughout the buffer fluid system (See Fig. 9).

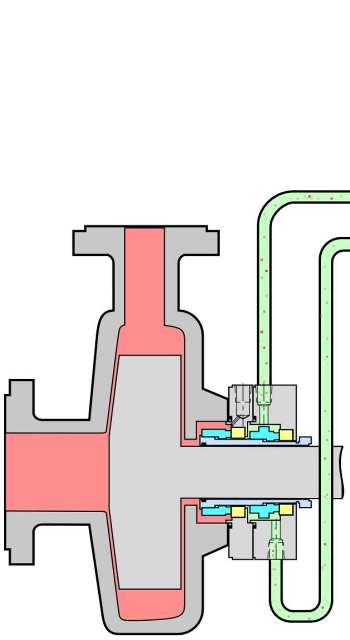

Figure 9. Process Fluids and Buffer Fluid Completely Miscible

When the fluids completely mix, it is reasonable to assume that the composition of the mixture is consistent throughout the buffer system. The buffer fluid will be uniformly contaminated at the seal, in the connecting tubing and in the reservoir. The leakage past the outer seal to atmosphere will contain the same composition as the bulk fluid in the system. This is an important consideration where there are environmental considerations for process leakage to atmosphere. The actual accumulation of process fluid will be a function of the system volume, the seal volumetric leakage rates, and time. An example of the contamination of the barrier fluid is given in the graph below (See Fig. 10).

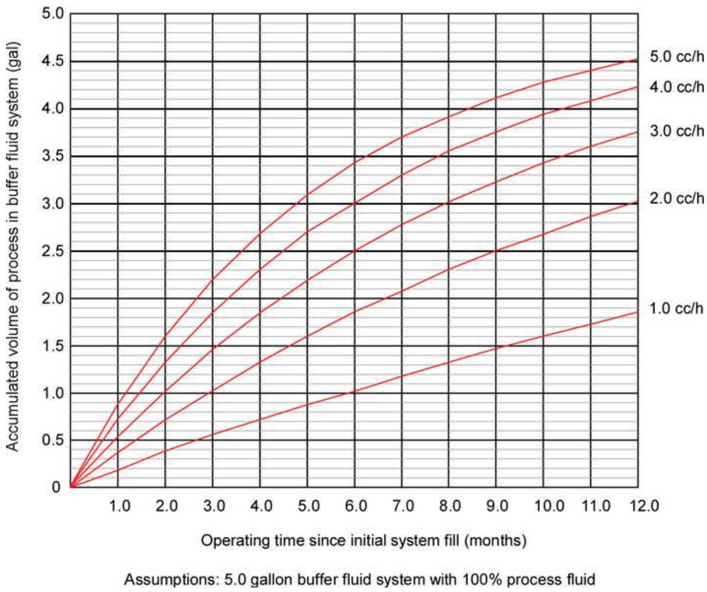

Figure 10. Example of Accumulation of Process Fluid in Buffer Fluid System

Arrangement 2 seals are commonly used in light hydrocarbon applications. Leakage past the inner seal will flash or vaporize as the pressure decreases. The resulting vapor bubbles migrate to the top of the reservoir in the Plan 52 and are vented to a flare or vapor recovery system. Some of the vaporized process will dissolve into the buffer fluid and remain in the fluid. Many light end products will contain some carryover of heavy products which will not evaporate and will remain in the buffer fluid. Buffer fluids in most light hydrocarbon applications however will remain relatively clean in operation.

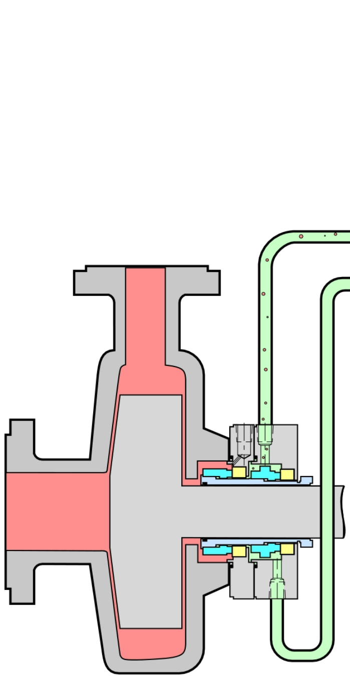

Figure 11. Volatile Process Fluid in Buffer Fluid

The actual accumulation of dissolved process fluid in the buffer fluid will be a function of the buffer fluid, the process fluid, the system temperature, and the system pressure. In most cases, the small amount of dissolved gases in the buffer fluid does not adversely affect seal performance

Other Sources of Contamination

Process leakage is not the only source of contamination in a buffer fluid system. Plan 52 reservoirs are connected to a flare or vapor recovery system. This connection point is often an overhead flare or recovery header (piping) which collects waste streams from multiple sources throughout the plant. Excessive pressure or level in this header can cause fluid in these lines to leak back down the connection line and contaminate the buffer fluid. This connection line will contain a check valve but defective or malfunctioning valves can allow some contamination back into the buffer system. The connection line from the reservoir should be piped to the top side of the horizontal flare header pipe to minimize liquid leakage from entering the connection line.

Another source of barrier of buffer fluid contamination can come from the seals themselves. Seals may fail for a variety of reasons. Some of these failure mechanisms may result in heavy contact between metal components or high wear of seal faces. Any failure mechanism which creates debris will contaminate the buffer fluid system. It is important to consider that even very small size debris (less than one micron) in the barrier or buffer fluid can negatively affect the performance of the seals.

Changing Barrier and Buffer Fluids

When should the user change barrier and buffer fluids? What should users do during shutdowns? What should they do when they replace the seal? These are common questions from end users with barrier or buffer fluid systems.

Whenever a seal is first installed or is removed for repair, the end user has the opportunity to ensure that the reservoir, piping/tubing, and other auxiliaries are clean and free from contamination. The entire system must be flushed with a suitable solvent or fluid to remove any solid debris or other liquids. The system must then be completely drained and, if required, blown clear with dry nitrogen prior to filling the system with the correct barrier or buffer fluid.

In operation, barrier and buffer fluids can degrade and become contaminated as discussed above. To obtain the most reliable seal performance, the barrier and buffer fluid should be changed at regular intervals. The actual change intervals will vary depending upon the nature of the barrier or buffer fluid, the volume of the system and the operating conditions. In general, for lower temperature barrier and buffer fluids should be changed once per year. Higher temperature systems should be changed out more frequently. In some very high temperature systems, fluids may need to be changed out three or four times per year. Systems with very large volumes of barrier or buffer fluids may require less frequent change intervals. Sudden changes in appearance, such as the buffer fluid turning dark, may indicate that the system has become contaminated or degraded and require immediate attention.

The best way to change a barrier or buffer fluid is to shut down the equipment, block in the pump, and depressurize the pump and piping plan. The operator will then completely drain the barrier or buffer fluid, refill the system, and restart the pump. This minimizes the opportunity for creating dry running conditions in the seal or exposing the operator to process fluids. In some cases, end users are reluctant to shut down an operating pump and have developed procedures for “simultaneously” draining and refilling the buffer or barrier fluid. This is done without significantly changing the level or pressure in the system. While these techniques do not completely change out the fluid, they have proven successful in the field but rely on operators strictly following the approved procedure.

SYSTEM CURVES AND PUMPING RING PERFORMANCE

Barrier and buffer fluid systems are small versions of a typical centrifugal pump system and are found in Plan 52 and 53 piping plans. The rotation of the seal parts, acting as an impeller, imparts energy (head) into the fluid. This fluid is directed into a piping system which is defined by the piping plan. Flow through the piping plan creates a resistance which is defined by a system curve. The flow rate of the barrier or buffer fluid will stabilize when the head-flow curve of the seal intersects the system curve of the piping plan.

There is one important difference between a standard pumping system and piping plan. Pumping rings or devices in Plan 52 and 53 systems generate very little head. While the seal components are rotating at the same rotational speed as the impeller, the seal components are very small and barrier or buffer fluid flows through restricted passages in the seal gland. The result is that pumping rings generally only generate a couple of meters or less of head. The flow rates are also generally on the order a few liters/min (gallons/min). The figure below shows the characteristics of a typical pumping device in a dual mechanical seal (See Fig. 12).

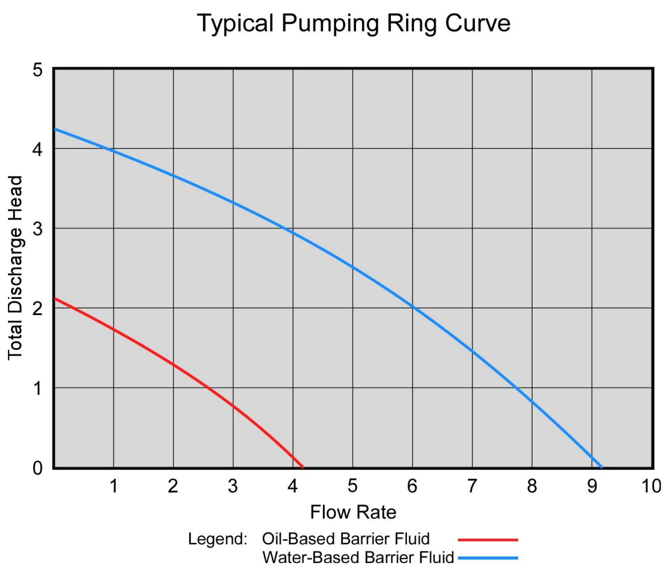

Figure 12. Representative Pumping Ring Curve

The flow rate of barrier and buffer fluids are controlled by the same parameters as any piping systems. The head and flow will increase with an increase in seal diameter or speed. The flow rate will also increase by streamlining the passages in the seal gland and creating effective tangential outlets or cutwaters. The pressure drops defined by the system curve will decrease as the pipe/tubing diameter increases, the tubing length is reduced, the number of fittings and components decreases, and the viscosity of the barrier or buffer fluid decreases. The figure below shows the characteristics of a typical system curve in a dual seal support system (See Fig. 13).

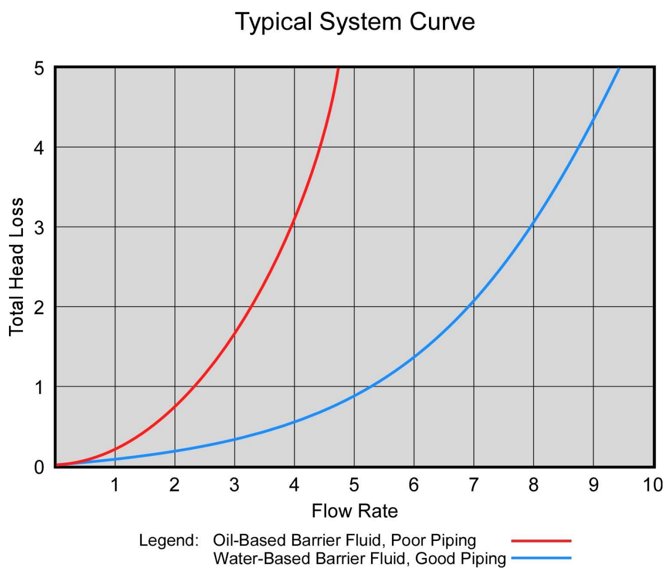

Figure 13. Representative Dual Liquid Seal System Curve

The barrier or buffer fluid rate will be determined both the pumping ring curve and system curve (See Fig. 14). Higher viscosity fluids will result in lower head generation and higher friction losses in the system resulting in low flow rates. Low viscosity fluids have higher head generation and lower friction losses resulting in higher flow rates. Considering all other factors, users should consider using the lowest viscosity barrier or buffer fluid option.

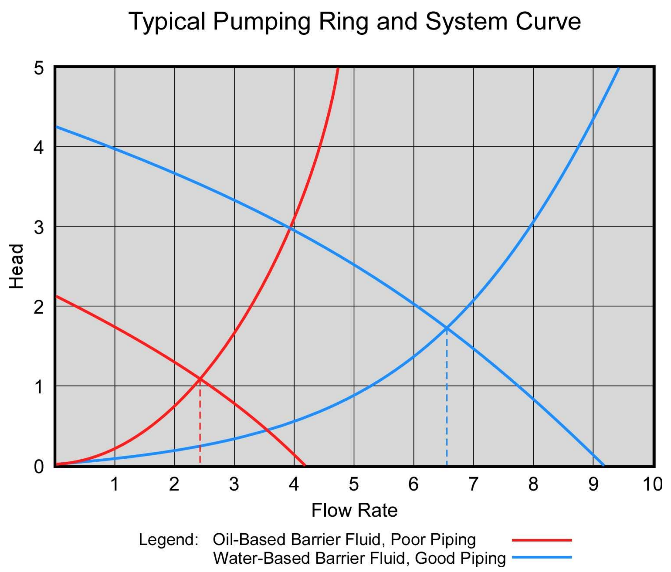

Figure 14. Combined Pumping Ring and System Curves

On Plan 52 and Plan 53A systems, it is also critical to keep the level of the buffer or barrier fluid near the middle of the site glass. If the fluid level in the reservoir drops below the return line from the seal, the flow rate of the barrier or buffer fluid will decrease dramatically resulting in higher fluid temperatures and reduced seal reliability. This may cause other issues such as increased mixing or aeration of the fluid with the vapor in the reservoir.

Frequently Asked Questions

What is the difference between a buffer fluid and barrier fluid?

The terms barrier fluid and buffer fluid are often used interchangeably while, in fact, they have two distinct meanings. A “buffer” fluid is used in Arrangement 2 seal designs (unpressurized) and is used to collect process seal leakage past the inner seal. A “barrier” fluid is used in Arrangement 3 seal designs (pressurized) and prevents process leakage to atmosphere by providing the environment for both the inner and outer seals. In practice, the most commonly used fluids are suitable for use as both a barrier fluid or buffer fluid.

The end user wants to use another fluid from their process as a barrier fluid? Is this acceptable?

The final selection of the barrier fluid depends upon many different factors and ultimately the end user has the responsibility to approve the final selection. Some plants will use process streams as a barrier fluid due to the easy access to the fluid and the low internal cost. Seal OEMs and users however must be careful about approving or endorsing barrier fluids that we do not have any experience with. Recommendations should be from the list of fluids shown in Table 1 or from fluids that the user has successful experience with. If these fluids do not meet the operating requirements of the application or are not acceptable to the user, the user should contact the seal OEM for additional recommendations.

Can we mix different types of barrier or buffer fluids?

In general, it is not recommended to mix different barrier or buffer fluids. It is obvious that mixing oil and water based fluids will result in an emulsion with unacceptable properties. Mixing oil based fluids from different manufacturers or fluids with different chemistries or viscosities is also not recommended without considering potential compatibility issues between the fluids. The best practice would be to drain the previous barrier or buffer fluid and clean the system before changing to a new fluid.

Are there additional considerations with the barrier fluid selection when using a Plan 54 circulator system?

Most Plan 54 systems use a positive displacement pump to circulate the barrier fluid and pressurize the seal and piping system. The positive displacement pump may have specific requirements for the fluid for reliable operation. These pumps generally operate better on higher viscosity fluids due to better lubrication of the pump and reduced slippage or recirculation of the fluid within the Plan 54 circulation pump itself. The lower viscosity requirements of the seal need to be weighed against the higher viscosity requirements of the circulation pump. Water or water based barrier fluids present special challenges in this area. Review the final barrier fluid selection with the systems supplier on Plan 54 applications.

CONCLUSIONS

Barrier and buffer fluids are an integral component of a dual liquid seal installation. The fluid not only serves the function of lubricating the seal faces but also must be function well when exposed to the process fluid and circulated through the sealing system. Matching the correct fluid to a specific application is a critical first step in a successful dual seal application.

Proper handling of the barrier fluid and the practices in maintaining the sealing systems play an equally important role in defining the overall reliability of a seal installation. Fortunately, there are large installed base and a mature set of best practices to guide the user towards successful dual seal reliability.

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APPENDIX A
Table 1
Recommended Barrier and Buffer Fluids

Barrier/Buffer Fluid Name	Applications	Process Temperature	Recommended Barrier Fluid Operating Temperature Range	Barrier Fluid Comments	General Comments
Water	Low duty, water, chemicals, food processing, pharmaceutical, biotech	1 to 121°C (33 to 250°F)	1 to 71°C (33 to 160°F)	Water is a poor lubricant and can only be used in low duty applications and at moderate temperatures. It is not recommended for seals with hard vs. hard face materials combinations.	A water barrier fluid is not regulated or restricted. However contaminated barrier or buffer fluids must be disposed of properly.
Ethylene Glycol/Water 50/50 mixture	Buffer fluid for light hydrocarbons applications	-35 to 100°C (-31 to 212°F)	-35 to 100°C (-31 to 212°F)	Ethylene glycol/water is excellent for general duty applications. The ethylene glycol must be free from additives. Automotive anti-freeze is not acceptable.	Ethylene glycol is considered a hazardous substance and is toxic if ingested. This fluid may not be allowed by local regulations or may be unacceptable in some applications due to process contamination.
Propylene Glycol/Water 50/50 mixture	Buffer fluid for light hydrocarbons applications	-33 to 100°C (-27 to 212°F)	-33 to 100°C (-27 to 212°F)	Propylene glycol/water barrier fluid is excellent for applications at moderate temperatures where water based fluids are required.	Propylene glycol is considered non-hazardous and can be safe for food grade applications.
Propanol	Cryogenic applications	-100 to 0°C (-148 to 32°F) See Note 1	-100 to 20°C (-148 to 68°F) See Note 1	Propanol is suitable in cryogenic applications where the barrier fluid will be exposed to low temperatures.	Propanol is considered to be environmentally acceptable. Pure grades are acceptable for food grade applications.
Diesel #2	Light hydrocarbon and medium duty applications	-10 to 60°C (14 to 140°F)	-10 to 60°C (14 to 140°F)	Diesel is excellent seal lubricant with low viscosity and excellent stability under moderate temperatures. Historically, it was one of the first and most widely used barrier fluids in light hydrocarbon installations.	Diesel has seen more limited use in recent years due to emissions concerns.

Barrier/Buffer Fluid Name	Applications	Process Temperature	Recommended Barrier Fluid Operating Temperature Range	Barrier Fluid Comments	General Comments
Typical PAO Example 1 See Note 3	General duty and high duty applications	0 to 204°C (32 to 400°F)	15 to 65°C (59 to 150°F)	This PAO fluid is a synthetic lubricant specifically designed as a barrier and buffer fluid for general and high duty application.	There are no specific environmental or safety concerns with exposure or disposal of synthetics lubricants.
Typical PAO Example 2 See Note 3	General duty and high duty applications	0 to 204°C (32 to 400°F)	15 to 65°C (59 to 150°F)	This PAO fluid is the original synthetic PAO designed specifically as a barrier/buffer fluid. It is the most widely used synthetic barrier fluid for seal applications.	There are no specific environmental or safety concerns with exposure or disposal of synthetics lubricants.
Typical PAO Example 3 See Note 3	General duty and high duty applications at high temperatures	80 to 300 °C (176 to 572°F) See Note 2	37 to 90 °C (99 to 194°F) See Note 2	This PAO fluid has a higher viscosity synthetic suitable for higher temperature applications.	There are no specific environmental or safety concerns with exposure or disposal of synthetics lubricants.
Typical PAO Example 4 See Note 3	General duty and high duty applications at high temperatures	80 to 300 °C (176 to 572°F) See Note 2	37 to 90 °C (99 to 194°F) See Note 2	This PAO fluid has a higher viscosity synthetic suitable for higher temperature applications.	There are no specific environmental or safety concerns with exposure or disposal of synthetics lubricants.
Typical PAO Example 5 See Note 3	High temperature applications	80 to 400 °C (176 to 752°F) See Note 2	37 to 90 °C (99 to 194°F) See Note 2	This PAO fluid has a very high viscosity fluid which can only be used in high temperature applications.	There are no specific environmental or safety concerns with exposure or disposal of synthetics lubricants.

Note 1: The temperature ranges shown are general guidelines that indicate where these fluids have been successfully used in the field. In extreme temperature applications, other seal design features or effective piping plans may be required for successful applications. In some vertical cryogenic pumps, the seal chamber is isolated from the process fluid which allows more flexibility in the selection of a barrier fluid.

Note 2: In high temperature pumps, the selection of the barrier or buffer fluid, the design of the seal, the selection of inner seal piping plan (e.g. Plan 23 or Plan 32), the seal orientation (face-to-back, back-to-back, or face-to-face), the use of effective thermal breaks and isolation bushings, and the selection of the outer seal piping plan and auxiliaries are all critical to achieving reliable seal performance. No barrier fluid is stable at the extreme temperatures (greater than 200°C [400°F]) which can be seen at most refineries. The selection and design of the piping plans are required to maintain the barrier or buffer fluid at a lower temperature (e.g. less than 90°C [194°F]) during operation. In some cases, plants may desire to limit temperatures below 65°C [150°F] to minimize the operator’s exposure to hot piping or reservoirs. The user must also review the low temperature conditions in the seal chamber and piping system and ensure the viscosity does become excessive. This may require heating the seal piping system during stand-by conditions. For viscosities greater than 20 cP, a hard vs. hard face combination should be used to prevent blistering on carbon faces.

Note 3: The PAO barrier fluids listed above are listed generically to prevent endorsement of a specific brand or formulation.